# II. *Experiments and Obſervations on the ſpecific Gravities and attractive Powers of various ſaline Subſtances.* *By* Richard Kirwan, *Eſq. F. R. S.*

Read November 16, 1780.

THE doctrine of chymical affinities hath of late received great improvements from the labours of the very excellent Mr. BERGMAN of Upſal, and the ſtill later reſearches of Mr. WENTZEL; but the order of theſe attractions has hitherto been the only point attended to by theſe philoſophers, as well as by moſt preceding chymiſts: for I know of none, except Mr. MORVEAU of Dijon, who has thought of aſcertaining the various degrees of force of chemical attraction, by which one body acts on various other bodies, or even on the ſame body in various circumſtances. He has, however, ſo ably ſhewn the advantages ariſing from ſuch an inquiry, that I have made it the object of my attention, and beſtowed much pains on it for ſome time paſt; and have been thereby enabled to determine pretty exactly the proportion of the ingredients of many neutral ſalts, and the ſpecific gravity of the mineral acids in their pureſt ſtate, and free from all water. The principles on which theſe determinations are founded are the following.

1ſt. That the ſpecific gravity of bodies is as their weight, divided by the weight of an equal bulk of rain or diſtilled water, this being at preſent the ſtandard with which every other body is compared.

2dly. That if bodies, ſpecifically heavier than water, be weighed in air and in water, they loſe in water part of the weight which they were found to have in air; and that the weight ſo loſt is juſt the ſame as that of an equal bulk of water, and conſequently that their ſpecific gravity is equal to their weight in air, or *abſolute weight*, divided by their loſs of weight in water.

3dly. That if a ſolid, ſpecifically heavier than a liquid, be weighed firſt in air, and then in that liquid, the weight it loſes is equal to the weight of an equal volume of that liquid; and conſequently if ſuch ſolid be weighed firſt in air, then in water, and afterwards in any other liquid, the ſpecific gravity of this liquid will be as the weight loſt in it by ſuch ſolid, divided by the loſs of weight of the ſame ſolid in water. This method of finding the ſpecific gravity of liquids I have found much more exact than that by the areometer, or the compariſon of weights of equal meaſures of ſuch liquids and water, both of which are ſubject to ſeveral inaccuracies.

4thly. That where the ſpecific gravity of bodies is already known, the weight of an equal bulk of water may alſo be found, it being as the quotient of their abſolute weight divided by their ſpecific gravity. This I ſhall call their *loſs of weight* in water.

Hence, where the ſpecific gravity and abſolute weight of the ingredients of any compound are known, the ſpecific gravity of ſuch compound may eaſily be calculated as it ought to be intermediate betwixt that of the lighter and that of the heavier, according to their ſeveral proportions: this I call the *mathematical* ſpecific gravity. But, in fact, the ſpecific gravity of compounds, found by actual experiment, ſeldom agrees with that found by calculation, but is often greater without any diminution of the lighter ingredient. This increaſe of denſity muſt then ariſe from a cloſer union of the component parts to each other than either had ſeparately with its own integrant parts; and this more intimate union muſt proceed from the attraction or affinity of theſe parts to each other: I therefore imagined this attraction might be eſtimated by the increaſe of denſity or ſpecific gravity and was proportionable to it, but was ſoon undeceived.

I muſt alſo premiſe, that the abſolute weights of many ſorts of air have been accurately determined by Mr. FONTANA, at whoſe experiments I was preſent, the thermometer being at 55°, and the barometer at 29½ inches, or nearly ſo. Their weights were as follows:

| | |
|---|---|
| Cubic inch of common air | 0,385 |
| Fixed air | 0,570 |
| Marine air | 0,654 |
| Nitrous air | 0,399 |
| Vitriolic air | 0,778 |
| Alkaline air | 0,2 |
| Inflammable air | 0,03 |

## OF SPIRIT OF SALT.

From the time I firſt read in Dr. PRIESTLEY's Experiments on Air (that inexhauſtible ſource of future diſcoveries) of the exhibition of marine acid in the form of air, free from water; and that this air, reunited with water, formed an acid liquor in all reſpects the ſame as common ſpirit of ſalt; I conceived the poſſibility of diſcovering the exact quantity of acid in ſpirit of ſalt of any given ſpecific gravity, and by means of this the exact proportion of acid in all other acid liquors; for if a given quantity of pure fixed alkali were ſaturated, firſt by a certain quantity of ſpirit of ſalt, and then by determined quantities of the other acids, I concluded, that each of theſe quantities of acid liquor muſt contain the ſame quantity of acid, and this being known, the remainder being the aqueous part, this alſo muſt be known; but this concluſion intirely reſted on the ſuppoſition that the ſame quantity of all the acids was requiſite for the ſaturation of a given quantity of fixed alkali; for if ſuch given quantity of fixed alkali might be ſaturated by a ſmaller quantity of one acid than of another, the concluſion fell to the ground. This point might, indeed, be in ſome meaſure determined by weighing the neutral ſalts, formed by theſe acids, when thoroughly dry; but ſtill a ſource of inaccuracy remained: for if they were expoſed to a conſiderable heat, part of the acid would neceſſarily be expelled, and more of one acid than of another, and if the heat were not conſiderable, much of the water of cryſtallization would remain; ſo that if the weights were found to be equal, this equality could not be aſcribed to equal quantities of acid, but might perhaps ariſe from a ſmaller proportion of acid in one of them, and a larger proportion of water, and in another from a larger proportion of acid and a ſmaller proportion of water; and if the weights were unequal, no certain concluſion could be drawn. To obviate this difficulty I uſed the following expedient. 1ſt. I ſuppoſed the quantities of nitrous and vitriolic acids, neceſſary to ſaturate a given quantity of fixed alkali, exactly the ſame as that of marine acid whoſe quantity I determined; and to prove the truth of this ſuppoſition, I obſerved the ſpecific gravity of the ſpirit of nitre and oil of vitriol I made uſe of, and in which I ſuppoſed, from the trial with alkalies, a certain proportion of acid and water; I then added to theſe more acid and water, and calculated what their ſpecific gravities ſhould be upon the above ſuppoſition, and finding the reſult to tally with the ſuppoſition, I concluded the latter to be exact.

The experiments made on the marine acid were as follows.

I took two bottles, which I filled nearly to the top with diſtilled water, of which they contained in all 1399,9 gr. and introduced them ſucceſſively into two cylinders filled with marine air, which I had obtained from common ſalt by means of dilute oil of vitriol and heat, in a mercurial apparatus; and this proceſs I renewed until the water had imbibed, in eighteen days, about 794 cubic inches of the marine air. The thermometer did not riſe all this time above 55°, nor ſink, unleſs perhaps at night, under 50°, and the barometer was between 29 and 30 inches. This water, or rather ſpirit of ſalt, I then found to weigh 1920 gr. that is 520,1 more than before. The quantity of marine air abſorbed amounted then to 520,1 gr. I then examined the ſpecific gravity of this ſpirit of ſalt, and found it to be 1,225. Its loſs of weight in water (that is, the weight of an equal bulk of water) ſhould then be 1567,346 gr. nearly; but it contained only, as we have ſeen, 1399,9 gr. of water: therefore ſubtracting this from 1567,346, the remainder (that is, 167,446) muſt be the loſs of 520,1 gr. of marine acid; and conſequently the ſpecific gravity of the pure marine acid, in ſuch a condenſed ſtate as it is in when united to water, muſt be $\frac{520,1}{167,446} = 3,100$. But ſtill it might be ſuſpected, that the denſity of this ſpirit did not intirely proceed from the mere denſity of the marine acid, but in part alſo from the attraction of this acid to water, and though the length of time requiſite to make water imbibe this quantity of acid made me judge that the attraction was not very conſiderable, yet the following experiment was more ſatisfactory.

I expoſed 1440 gr. of this ſpirit to marine air for five days, the thermometer being at 50° or under; it then weighed 1562 gr. and conſequently imbibed 122 gr. of marine air; its ſpecific gravity was then 1,253, which agrees exactly with what it ſhould be by calculation.

N. B. I have not repeated the whole of theſe experiments, as they were very tedious; but I began them over again ſeveral times before I could aſcertain with any preciſion the quantity of marine air abſorbed, as, when the whole of a cylinder full of air was abſorbed, it was difficult to ſtop the bottles ſo as to prevent any mercury from falling in; and I was obliged every night to fill the cylinders with air, leſt if there remained but a ſmall quantity it might be imbibed before morning, and the mercury fall into the bottles. I alſo made ſome allowance for the common air which I could not avoid letting into the cylinder with the marine air, as will be very apparent to whoever repeats the experiment.

Being now ſatisfied I had diſcovered the proportion of acid and water in ſpirit of ſalt, I was impatient to find it in other acids alſo; and for that purpoſe I took 180 gr. of very ſtrong oil of tartar *per deliquium*, but of whoſe ſpecific gravity I can find no note, and found it to be ſaturated by 180 gr. of ſpirit of ſalt, whoſe ſpecific gravity was 1,225. Now, by calculation it appears, that 180 gr. of this ſpirit contains 48,7 gr. of acid and 131,3 of water, and hence I drew up the following table.

| Marine acid. | Water. | Specific Gravity. |
|---|---|---|
| Parts. | Parts. | |
| 48,7 | 50 | 1,497 |
| | 60 | 1,431 |
| | 70 | 1,381 |
| | 80 | 1,341 |
| | 90 | 1,308 |
| | 100 | 1,282 |
| | 110 | 1,259 |
| | 120 | 1,246 |
| | 130 | 1,223 |
| | 140 | 1,209 |
| | 150 | 1,196 |
| | 160 | 1,185 |
| | 170 | 1,175 |
| | 180 | 1,166 |
| | 190 | 1,158 |
| | 200 | 1,151 |
| | 210 | 1,144 |
| | 220 | 1,138 |
| | 230 | 1,132 |
| | 240 | 1,127 |
| | 250 | 1,122 |
| | 260 | 1,118 |
| | 270 | 1,114 |
| | 280 | 1,110 |
| | 290 | 1,106 |
| | 300 | 1,103 |
| | 310 | 1,100 |
| | 320 | 1,097 |
| | 330 | 1,091 |
| | 340 | 1,089 |
| | 350 | 1,086 |
| | 360 | 1,084 |
| | 370 | 1,082 |
| | 380 | 1,080 |
| | 390 | 1,078 |
| | 400 | 1,076 |
| | 410 | 1,074 |

The ſpecific gravity of the ſtrongeſt ſpirit of ſalt, made in the uſual way, is, according to Mr. BAUME, 1,187, and according to Mr. BERGMAN, 1,190; but we read in the Paris Memoirs for the year 1700, p. 191. that Mr. HOMBERG paſſed a ſpirit whoſe ſpecific gravity was 1,300; and that made by Dr. PRIESTLEY (ſee vol. III. p. 275.) muſt have been about 1,500.

Hence we ſee, that ſpirit of ſalt, whoſe ſpecific gravity is 1,261 or leſs, has little or no attraction with water, and therefore attracts none from air, and on that account does not heat a thermometer whoſe ball is dipped in it as ſpirit of vitriol and ſpirit of nitre do, as has lately been obſerved by the Friendly Society of Berlin.

This table is not exactly accurate, as I had not in this firſt experiment found the point of ſaturation as nicely as was requiſite. However, I have not corrected it, as the error is but ſmall, and the proportion may at any time be found by calculation; at leaſt when the ſpecific gravity of this ſpirit does not exceed 1,253. Whether the mathematical ſpecific gravity and that by obſervation differ in the higher degrees of ſpecific gravity, I have not examined; but the table is formed on the ſuppoſition that they do not.

Common ſpirit of ſalt is always adulterated with vitriolic acid, and therefore not fit for theſe trials.

Intending to determine by this experiment the proportion of acid, water, and fixed alkali in digeſtive ſalt, as it is called, I took 100 gr, of a ſolution of a tolerably pure vegetable alkali that had been three times calcined to whiteneſs, the ſpecific gravity of which ſolution was 1,097. I alſo diluted the ſpirit of ſalt with different portions of water; the ſpecific gravity of one ſort was 1,115, and of another 1,098.

I then found that the above quantity of the ſolution of a vegetable alkali required for its ſaturation 27 gr. of that ſpirit of ſalt whoſe ſpecific gravity was 1,098, and 23,35 gr. of that ſpirit of ſalt whoſe ſpecific gravity was 1,115. Now, 27 gr. of ſpirit of ſalt, whoſe ſpecific gravity is 1,098, contain 3,55 gr. of marine acid, as appears by calculation. As the principle on which this calculation, by which the proportion of ſubſtances in alloy is found, may not be generally known, I ſhall here mention them in the words of Mr. COTES.

"The *data* requiſite are the ſpecific gravities of the mixture "and of the two ingredients. . . . . Then, as the difference "of the ſpecific gravities of the mixture and the lighter ingre-"dient is to the difference of the ſpecific gravities of the mix-"ture and the heavier ingredient, ſo is the magnitude of the "heavier to the magnitude of the lighter ingredient. Then, "as the magnitude of the heavier multiplied into its ſpecific "gravity is to the magnitude of the lighter multiplied into its "ſpecific gravity, ſo is the weight of the heavier to the weight "of the lighter . . . . Then, as the ſum of theſe weights "is to the given weight of either ingredient, ſo is the weight "given to the weight of the ingredient ſought."

Thus, in this caſe, 1,098 − 1,000 = ,098 is the magnitude of the heavier ingredient, *viz.* the marine acid; and, 098 × 3,100 = 0,3038 the weight of the marine acid; and, on the other hand, 3,100 − 1,098 = 2,002 the magnitude of the water, and 2,002 × 1,000 = 2,002 its weight; the ſum of theſe weights is 2,3058 : then, if 2,3058 parts of ſpirit of ſalt contain 0,3038 parts acid, 27 gr. of this ſpirit of ſalt will contain 3,55 acid.

In the ſame manner it will be found, that 23,35 gr. of ſpirit of ſalt, whoſe ſpecific gravity was 1,115, contained 3,55 gr. acid.

The point of ſaturation was pretty accurately found by putting the glaſs cylinder which contained the alkaline ſolution on the ſcale of a very ſenſible balance, and at the ſame time weighing the acid liquor in another pair of ſcales, when the loſs of weight indicated the eſcape of nearly equal quantities of the fixed air contained in the ſolution; then the acid was gradually added, by dipping a glaſs rod into it, to the top of which a ſmall drop of acid adhered: with this the ſolution was ſtirred, and very ſmall drops taken up and laid on bits of paper ſtained blue with radiſh juice. As ſoon as the paper was in the leaſt reddened, the operation was completed ſo that there was always a very ſmall exceſs of acid, for which half a grain was conſtantly allowed; but no allowance was made for the fixed air, which always remains in the ſolution; but as, on this account, only a ſmall quantity of the alkaline ſolution was uſed, this proportion of fixed air muſt have been inconſiderable. If an ounce of the ſolution had been employed, this inappreciable portion of fixed air would be ſufficient to cauſe a ſenſible error: for I judged of the quantity of fixed air loſt by the difference betwixt the weight added to the 100 gr. and the actual weight of the compound. When this difference amounted to 2,2 gr. then I judged the whole of the fixed air expelled, and found it to be ſo, as 100 gr. of this alkaline ſolution, being evaporated to dryneſs in a heat of 300°, left a reſiduum which amounted to 10½ gr.; which 10½ gr. contained 2,2 gr. of fixed air, as will hereafter be ſeen.

Hence 8,3 gr. of pure vegetable fixed alkali, free from fixed air and water, or 10,5 of mild fixed alkali, were ſaturated by 3,55 gr. of pure marine acid, and conſequently the reſulting neutral ſalt ſhould, if it contained no water, weigh 11,85 gr.; but the ſalts reſulting from this union (the ſolution being evaporated to perfect dryneſs in a heat of 160° kept up for four hours) weighed at a medium 12,66 gr. Of this weight 11,85 gr. were acid and alkali; therefore the remainder, *viz.* 0,81 of gr. were water; therefore 100 gr. of perfectly dry, digeſtive ſalt contain 28 gr. acid, 6,55 water, 65,4 of fixed alkali.

I was then curious to compare my experiments with thoſe made by others, but could not find any made with ſufficient preciſion but thoſe of Mr. HOMBERG in the Paris Memoirs for 1699. However, as to ſpirit of ſalt I did not think proper to compare them, as he mentions that his could diſſolve gold, and therefore was probably impure.

## OF SPIRIT OF NITRE.

The common reddiſh brown or greeniſh ſpirit of nitre containing, beſides acid and water, a certain portion of phlogiſton, and being alſo mixed with ſome portion of the acid of ſea ſalt, I judged unfit for theſe trials, and therefore uſed only the dephlogiſticated ſort, which is quite colourleſs, and reſembles pure water in its appearance. This pure acid cannot be made to exiſt in the form of air, as Dr. PRIESTLEY has ſhewn; for when it is deprived of water and phlogiſton, and furniſhed with a due proportion of elementary fire, it ceaſes to have the properties of an acid, and becomes dephlogiſticated air; I could not, therefore, determine its proportion in ſpirit of nitre as I had done that of the marine acid, but was obliged to uſe another method.

1ſt. To 1963,25 gr. of this ſpirit of nitre, whoſe ſpecific gravity was 1,419, I gradually added 179,5 gr. of diſtilled water, and when it cooled I found the ſpecific gravity of this mixture 1,389.

2dly. To 1984,5 gr. of this I again added 178,75 gr. of water; its ſpecific gravity was then 1,362.

I then took 100 gr. of a ſolution of fixed vegetable alkali, whoſe ſpecific gravity was 1,097, the ſame I had before uſed in the trials with ſpirit of ſalt, and found this quantity of alkali to be ſaturated by 11 gr. of the ſpirit of nitre, whoſe ſpecific gravity was 1,419; and by 12 gr. of the ſpirit, whoſe ſpecific gravity was 1,389; and by 13,08 of that, whoſe ſpecific gravity was 1,362. The quantities here mentioned were the medium of five experiments. I found it neceſſary to dilute the nitrous acid with a ſmall proportion of water, of which I kept an account. When I neglected this precaution, I found that part of the acid was phlogiſticated, and went off with the fixed air. Note alſo, that after each affuſion of acid ten minutes were allowed to the matters to unite, a precaution which I alſo found abſolutely neceſſary.

Hence (upon the ſuppoſition that a given quantity of fixed vegetable alkali is ſaturated by the ſame weight of both acids) we ſee that 11 gr. of ſpirit of nitre, whoſe ſpecific gravity is 1,419, contain the ſame quantity of acid as 27 gr. of ſpirit of ſalt, whoſe ſpecific gravity is 1,098, that is, 3,55 gr.; the remainder of 11 gr. is therefore mere water, *viz.* 7,45 gr.; conſequently, if the denſity of the acid and water had not been increaſed by their union, the ſpecific gravity of the pure and mere nitrous acid ſhould be 11,8729; for the ſpecific gravity of this acid ſhould be as its abſolute weight divided by its loſs of weight in water, and this loſs ſhould be as the total loſs of theſe 11 gr. minus the loſs of the aqueous part. Now the total loſs $= \frac{11}{1,419} = 7,749$, and the loſs of the aqueous part $= 7,45$, and conſequently the loſs of the acid part is $7,749 - 7,45 = 0,299$, and therefore the ſpecific gravity of the acid part, that is, of the pure nitrous acid, is $\frac{3,55}{0,296} = 11,8729$.

But it is well known, that the denſity of the nitrous acid, as well as that of the vitriolic, is increaſed by its union with water; and therefore the loſs above found is not the *whole* of its real loſs in its natural ſtate (if it could be ſo found), but partly the loſs that ariſes from the denſity that accrues to it from its union with water: for ſince its denſity is increaſed by this union, its loſs is leſs than it would be if the nitrous acid had only its own proper denſity, and conſequently the ſpecific gravity above found is greater than its real ſpecific gravity.

To determine, therefore, the real ſpecific gravity of this acid in its natural ſtate, the quantity of *accrued* denſity muſt be found, and ſubtracted from the ſpecific gravity of the ſpirit of nitre, whoſe true mathematical ſpecific gravity will then appear. I endeavoured to effect this by mixing different portions of ſpirit of nitre and water, remarking the diminution of their joint volume below the ſum of the ſpaces occupied by their ſeparate volumes; but could never attain a ſufficient degree of preciſion. The following method, though not exactly accurate I found more ſatisfactory. 12 gr. of the ſpirit of nitre, whoſe ſpecific gravity by obſervation was 1,389, contained as I ſuppoſed from the former experiment 3,55 gr. of acid, and 8,45 of water; then if the ſpecific gravity of the pure nitrous acid were 11,872, the ſpecific gravity of this compound of acid and water ſhould be 1,371; for the loſs of 3,55 gr. acid ſhould be 0,299, and the loſs of the water 8,45; the ſum of the loſſes 8,749. $\frac{12}{8{,}749} = 1{,}371$; but, as I already ſaid, the ſpecific gravity by obſervation was 1,389, therefore the *accrued* denſity in this caſe was at leaſt ,018, the difference betwixt 1,389 and 1,371. I ſay *at leaſt*, for as the ſpecific gravity 11,872 was certainly too high, the loſs of 3,55 gr. acid was certainly too ſmall; and if it were greater, the mathematical ſpecific gravity 1,371 would have been ſtill lower. However, ,018 is certainly a near approximation to the degree of denſity that accrues to 3,55 gr. acid by their union to 7,45 gr. of water, and differs inconſiderably from the truth, as will appear by the ſequel: therefore ſubtracting this quantity from 1,419 we have nearly the mathematical ſpecific gravity of that proportion of acid and water, namely, 1,401. And ſince 11 gr. of this ſpirit of nitre contain 3,55 gr. acid and 7,45 of water, its loſs of weight ſhould be $\frac{11}{1{,}401} = 7{,}855$, and ſubtracting the loſs of the aqueous part from this, the remainder 0,405 is the loſs of the 3,55 gr. acid, and conſequently the true ſpecific gravity of the pure and mere nitrous acid is $\frac{3{,}55}{0{,}405} = 8{,}7654$: this being ſettled, the mathematical ſpecific gravity and true increaſe of denſity of the above mixtures will be found. Thus the mathematical ſpecific gravity of 12 gr. of that ſpirit of nitre, whoſe ſpecific gravity by obſervation was 1,389, muſt be 1,355, ſuppoſing it to contain 3,55 gr. acid and 8,45 of water; for the loſs of 3,55 gr. acid is $\frac{3,55}{8,763}=0,405$, and the loſs of water 8,45; the ſum of theſe loſſes is 8,855. Then, $\frac{12}{8,855}=1,355$, and conſequently the accrued denſity is $1,389-1,355=,034$. In the ſame manner it will be found, that the mathematical ſpecific gravity of 13,08 gr. of that ſpirit of nitre, whoſe ſpecific gravity by obſervation was 1,362, muſt be 1,315, and conſequently its accrued denſity ,047.

But the whole ſtill reſts upon the ſuppoſition that each of theſe portions of ſpirit of nitre contain 3,55 gr. of acid. To verify this ſuppoſition, I could think of no better method than that of examining the mathematical ſpecific gravities of the firſt mixture I had made of ſpirit of nitre and water in large quantities; for if the mathematical ſpecific gravities of theſe agreed exactly with thoſe of the quantities I had ſuppoſed in ſmaller portions of each, I could not but conclude, that the ſuppoſitions of ſuch proportions of acid and water, as I had determined in each, was juſt; and that this was the caſe will appear by the following calculations.

1ſt. When to 1963,25 gr. of ſpirit of nitre, whoſe ſpecific gravity was 1,419, 179,5 gr. of water were added, the quantity of acid upon the above ſuppoſition ſhould be 634,53 gr.; for :: 11 . 3,55 :: 1963,25 . 634,53 . the quantity of water in thoſe 1963,25 gr. of ſpirit of nitre ſhould then be 1328,72, and after adding 179,5 gr. of water, the whole quantity of acid and water ſhould be 2142,75, the loſs of acid was $\frac{634\ 53}{8,7654}=$ 71,24, and the ſum of the loſſes 1580,46: then the mathematical ſpecific gravity ſhould be $\frac{2142{,}75}{1580{,}46} = 1{,}355$, which is exactly the ſame as that which was found in 12 gr. of this ſpirit of nitre, on the ſuppoſition that they contained 3,55 gr. acid.

Again: when to 1984,5 gr. of this mixture I added 178,75 gr. of water, the whole quantity of diluted ſpirit of nitre was 2163,25 gr. and the quantity of acid in 1984,5 gr. was 587,081 gr. for ∵ 12 . 3,55 :: 1984,5 . 587,081; the loſs of this quantity of acid is 66,96 gr. and the ſum of the loſſes of acid and water is 1643,129 gr.; and conſequently the mathematical ſpecific gravity ſhould be $\frac{2163{,}75}{1643{,}125} = 1{,}315$, which is the ſame as that determined in 13,08 gr. of the ſame mixture.

By continuing theſe mixtures until I found the mathematical ſpecific gravity and that by obſervation nearly to coincide, I was enabled to draw up the following table, in which if any errors be found, I hope they will be excuſed, from the impoſſibility of avoiding them where the weights muſt be found with ſuch extreme preciſion: the two firſt ſeries were only found by analogy.

Spirit

| Spirit of nitre. | Acid. | Water. | Accrued denſity. | Mathematical ſpecific gravity. | Specific gravity by obſervation | Attract. of the acid to water. | Attract. of water to the acid. |
|---|---|---|---|---|---|---|---|
| Grs. | Grs. | Grs. | | | | | |
| 9 | – – | 5,45 | ,000 | 1,537 | 1,537 | – – | – – |
| 10 | – – | 6,45 | ,009 | 1,458 | 1,467 | ,009 | ,054 |
| 11 | – – | 7,45 | ,018 | 1,401 | 1,419 | ,018 | ,045 |
| 12 | – – | 8,45 | ,034 | 1,355 | 1,389 | ,027 | ,036 |
| 13,08 | – – | 9,53 | ,047 | 1,315 | 1,362 | ,036 | ,027 |
| 14,15 | – – | 10,6 | ,051 | 1,286 | 1,337 | ,045 | ,018 |
| 15,23 | – – | 11,68 | ,054 | 1,260 | 1,314 | ,054 | ,009 |
| 16,305 | – – | 12,755 | ,054 | 1,238 | 1,292 | ,054 | ,009 |
| 17,38 | – – | 13,83 | ,051 | 1,220 | 1,271 | | |
| 18,445 | – – | 14,9 | ,047 | 1,205 | 1,252 | | |
| 19,53 | – – | 15,98 | ,044 | 1,191 | 1,235 | | |
| 20,605 | – – | 17,055 | ,042 | 1,180 | 1,222 | | |
| 21,68 | – – | 18,13 | ,040 | 1,177 | 1,217 | | |
| 22,755 | – – | 19,205 | ,038 | 1,160 | 1,198 | | |
| 23,83 | – – | 20,28 | ,036 | 1,152 | 1,188 | | |
| 24,905 | – – | 21,45 | ,033 | 1,144 | 1,177 | | |
| 26,17 | – – | 22,62 | ,030 | 1,132 | 1,162 | | |
| 27,34 | 3,55 | 23,79 | ,027 | 1,130 | 1,157 | | |
| 28,51 | – – | 24,96 | ,026 | 1,124 | 1,150 | | |
| 29,68 | – – | 26,13 | ,024 | 1,114 | 1,138 | | |
| 30,85 | – – | 27,30 | ,022 | 1,113 | 1,135 | | |
| 32,02 | – – | 28,47 | ,020 | 1,109 | 1,129 | | |
| 33,09 | – – | 29,54 | ,018 | 1,102 | 1,120 | | |
| 34,26 | – – | 30,71 | ,016 | 1,101 | 1,117 | | |
| 35,43 | – – | 31,88 | ,014 | 1,097 | 1,111 | | |
| 36,60 | – – | 33,05 | ,012 | 1,094 | 1,106 | | |
| 37,77 | – – | 34,22 | ,010 | 1,090 | 1,100 | | |
| 38,94 | – – | 35,39 | ,008 | 1,088 | 1,096 | | |
| 40,11 | – – | 36,56 | ,006 | 1,085 | 1,091 | | |
| 41,28 | – – | 37,73 | ,004 | 1,082 | 1,086 | | |
| 42,45 | – – | 38,90 | ,002 | 1,080 | 1,082 | | |

The intermediate ſpecific gravities may be found by taking an arithmetical mean between the ſpecific gravities by obſervation betwixt which that ſought lies, and noting how much it exceeds or falls ſhort of ſuch arithmetical mean; and then taking alſo an arithmetical mean betwixt the mathematical ſpecific gravities betwixt which that ſought for muſt lie, and a proportionate exceſs or defect.

I have added a column of attraction of the nitrous acid to water as far as it keeps pace with the increaſe of denſity, but no farther, as I am unacquainted with the law of its further increaſe.

The ſpecific gravity of the ſtrongeſt ſpirit of nitre yet made is, according to Mr. BAUME, 1,500; and according to Mr. BERGMAN, 1,586.

I next proceeded to examine the proportion of acid, water, and fixed alkali in nitre, in the ſame manner as I had before done that in digeſtive ſalt, and found that 100 gr. of perfectly dry nitre contain 28,48 gr. acid, 5,2 of water, and 66,32 of fixed alkali.

I ſhall now compare the reſult of theſe experiments with thoſe of Mr. HOMBERG.

The ſpecific gravity of the ſpirit of nitre which Mr. HOMBERG made uſe of was 1,349; and of this, he ſays, 1 oz. 2 dr. and 36 gr. that is, 621 Troy, are requiſite to ſaturate 1 French (oz. 472,5 Troy) of dry ſalt of tartar; according to my computation 613 gr. are ſufficient; for this ſpecific gravity lies between the tabular ſpecific gravities by obſervation 1,362 and 1,337, and is nearly an arithmetical mean between them. The correſponding mathematical ſpecific gravity lies betwixt the tabular quantities 1,315 and 1,286, and is nearly 1,300. Now, the proportion of acid and water in this is, 2,629 of acid, and

$$7{,}465 \text{ of water; for } - \begin{array}{r} 8{,}765 \\ 1{,}300 \\ \hline \end{array} \quad \begin{array}{r} 8{,}765 \times .300 \\ \hline \end{array}$$

$$= 7{,}465 \text{ water and } = 2{,}629 \text{ of acid;}$$

and the ſum of both is 10,044. Now, ſince 10,5 gr. mild vegetable fixed alkali require 3,55 gr. of acid for their ſaturation, 472,5 will require 159,7; therefore, if 10,044 gr. of nitre contain 2,629 gr. acid, the quantity of this ſpirit of nitre requiſite to give 159,7 will be 613,2 nearly, and hence the difference betwixt us is only about 8 gr.

2dly. Mr. HOMBERG ſays, he found his ſalt, when evaporated to dryneſs, to weigh 186 gr. more than before; whereas, by my experiment, it ſhould weigh but 92,8 gr. more than at firſt. I ſhall mention the cauſe of this difference in treating of tartar vitriolate, for it cannot be intirely attributed to the difference of evaporation.

3dly. Mr. HOMBERG infers, that 1 oz. (that is, 472,5 Troy gr.) of this ſpirit of nitre contains 141 gr. Troy of real acid: by my computation it contains but 123,08 gr. of real acid. This difference evidently proceeds from his neglecting the quantity of water that certainly enters into the compoſition of nitre; for he proceeds on this analogy, 621 . 186,6 :: 472,5 . 141.

The proportion of fixed alkali I have aſſigned to nitre is fully confirmed by a very curious experiment of Mr. FONTANA'S, inſerted in ROZIER'S Journal for November 1778. This ingenious philoſopher decompoſed 2 oz. of nitre by diſtilling it in a ſtrong heat for eighteen hours. After the diſtillation there remained in the retort a ſubſtance purely alkaline, amounting to 10 French dr. and 12 gr. Now 2 French oz. = 944 gr. Troy, and the alkaline matter amounts to 607 gr. Troy; and, according to my computation, 944 gr. of nitre ſhould contain 625 of alkali. So ſmall a difference may fairly be attributed to the loſs in transferring from one veſſel to another, weighing, filtering, evaporating, &c.

Mr. LAVOISIER, in the Paris Memoirs for the year 1776, has given us, after Dr. PRIESTLEY, the analyſis of the nitrous acid.

In 2 oz. French meaſure (=945 gr. Troy) of ſpirit of nitre, whoſe ſpecific gravity was 1,3160, he diſſolved 2 oz. and 1 dr. of mercury; the quantity of air obtained during the ſolution was 190 cubic inches French (=202,55 Engliſh). This air was all nitrous. There remained a white mercurial ſalt, which, being diſtilled, afforded 12 cubic inches (=12,785 Engliſh) of air mixed with red vapours, and which differed little from common air. There afterwards aroſe 224 cubic inches (=238,56 Engliſh) of dephlogiſticated air, during the production of which, the mercury was almoſt revivified, there remaining but a few grains of a yellow ſublimate. The 12 inches of air mixed with red vapours aroſe, he ſays, from a mixture of 36 cubic inches of nitrous air (=38,34 Engliſh) and 14 of dephlogiſticated air (14,91 Engliſh); and as the mercury was almoſt wholly revived, he concludes, theſe airs aroſe from the nitrous acid, and formed it; and hence infers, that 16 oz. of this ſpirit of nitre (=7560 gr. Troy) contained 13 oz. 7 dr. 36$\frac{1}{5}$ gr. (that is, 6589 gr. Troy) of water, and conſequently only 971 gr. Troy of real acid, and therefore 2 oz. of this ſpirit of nitre contained but 120 gr. Troy of real acid: but, by my calculation, 2 oz. of this ſpirit of nitre contained 213 gr. acid; for its mathematical ſpecific gravity is 1,265. The ſame weight of acid will alſo be found in it by computing the weight of the volumes of the different airs he himſelf found it conſiſt of, or at leaſt to afford by its decompoſition; for 202,55 cubic inches of nitrous air weigh, by Mr. FONTANA's experiment, 80,8174 gr. Troy, and 238,56 inches of dephlogiſticated air weigh 100,1952 gr. Troy, and adding to theſe the weight of 38,34 inches of nitrous air, and of 14,91 of dephlogiſticated air, which made the 12 cubic inches of air mixed with red vapours, we ſhall find the whole weight of theſe airs to be 202,181 gr.;

the few grains wanting of 213 gr. may be accounted for from the abſorption of the water in which he received the airs, and by allowing for that ſtill remaining in the yellow ſublimate.

## OF OIL OF VITRIOL.

The oil of vitriol I made uſe of was not perfectly dephlogiſticated; but though pale yet a little inclined to red. It contained ſome whitiſh matter, as I perceived by its growing milky on the affuſion of pure diſtilled water. How far this may alter the reſult of the following experiments I have not tried; but believe it to be as pure as that which is commonly uſed in all experiments, and therefore the fitteſt for my purpoſe.

To 2519,75 gr. of this oil of vitriol, whoſe ſpecific gravity was 1,819, I gradually added 180 gr. of diſtilled water, and ſix hours after found its ſpecific gravity to be 1,771.

To this mixture I again added 178,75 gr. of water, and found its ſpecific gravity, when cooled to the temperature of the atmoſphere, to be 1,719; it was then milky.

I then ſaturated the ſame quantity of the oil of tartar above mentioned with each of theſe ſorts of oil of vitriol in the manner already mentioned, and found the ſaturation to be effected (taking the medium of five experiments) by 6,5 gr. of that whoſe ſpecific gravity was 1,819; by 6,96 gr. of that whoſe ſpecific gravity was 1,771; and by 7,41 of that whoſe ſpecific gravity was 1,719.

I was obliged to add a certain proportion of water to each of theſe ſorts of oil of vitriol; for when they were not diluted, I perceived that part of the acid was phlogiſticated, and went off with the fixed air; but knowing the quantity of water that was added, it was eaſy to find, by the rule of proportion, the quantity of each ſort of oil of vitriol that was taken up by the alkali.

Hence I ſuppoſed, that each of theſe quantities of oil of vitriol of different denſities contained 3,55 gr. of acid, as they ſaturated the ſame quantity of vegetable fixed alkali as 11 gr. of ſpirit of nitre, which contained that quantity of acid.

I then endeavoured to find the ſpecific gravity of the pure vitriolic acid in the ſame manner as I before had that of the nitrous, as it cannot be had in the ſhape of air unleſs united to ſuch a quantity of phlogiſton as quite alters its properties. The loſs of 6,5 gr. of oil of vitriol, whoſe ſpecific gravity is 1,819 is $\frac{6{,}5}{1{,}819} = 3{,}572$; but as theſe 6,5 gr. contained, beſides 3,55 gr. acid, 2,95 of water, the loſs of this muſt be ſubtracted from the intire loſs, and then the remainder 0,622 is the loſs of the pure acid part in that ſtate of denſity to which it is reduced by its union with water. The ſpecific gravity therefore of the pure vitriolic acid in this ſtate of denſity is $\frac{3{,}55}{0{,}622} = 5{,}707$. But to find its natural ſpecific gravity we muſt find how much its denſity is increaſed by its union with this quantity of water: and, in order to obſerve this, I proceeded as before with the nitrous acid. 6,96 gr. of oil of vitriol, whoſe ſpecific gravity was 1,771, contained 3,55 gr. acid, and 3,41 of water; then its ſpecific gravity by calculation ſhould be 1,726, for the loſs of 3,55 gr. acid is $\frac{3{,}55}{5{,}707} = 0622$; the loſs of 3,41 gr. water is 3,41; the ſum of the loſſes 4,032. Then, $\frac{6{,}96}{4{,}032} = 17{,}261$; therefore the *accrued* denſity is $1{,}771 - 1{,}726 = {,}045$. Taking this therefore from 1,819, its mathematical ſpecific gravity will be 1,774, then the loſs of 6,5 gr. of oil of vitriol, whoſe ſpecific gravity by obſervation is 1,819, will be found to be $\frac{6,5}{1,774} = 3,664$; but of this 2,95 gr. are the loſs of the water it contains, and the remainder 0,714 * are the loſs of the mere acid part. Then, $\frac{3,55}{0,715} = 4,9649$ is nearly the true ſpecific gravity of the pure vitriolic acid.

I then found the true increaſe of denſity ariſing from the union of the vitriolic acid and water in the foregoing mixtures, and obſerved, that in oil of vitriol, whoſe ſpecific gravity was 1,771, it was 0,84, and in that whoſe ſpecific gravity was 1,719, it was 0,100.

To obtain a ſynthetical proof of theſe deductions, I compared them with the ſpecific gravities of the firſt mixtures I had made; for if theſe deductions were true, the mathematical ſpecific gravities, and the *accrued* denſities, added to each other, ſhould amount to the ſame quantity as the ſpecific gravities by obſervation; and this I found to happen very nearly; for in the firſt experiment, where 2519,75 gr. of oil of vitriol, whoſe ſpecific gravity was 1,819, were mixed with 180 gr. of water, that oil of vitriol contained by my calculation 1376,171 gr. of acid and 1143,597 gr. of water, beſides the 180 gr. of water that were added to it, the loſs of the acid was $\frac{1376,171}{4,964} = 277,22$. The whole quantity of oil of vitriol was 2699,75 gr.; then the ſum of the loſſes was 1600,81; and therefore the mathematical ſpecific gravity $\frac{2699,75}{1600,81} = 1,686$; to which, adding ,084 the degree of accrued denſity, the ſpecific gravity by obſervation ſhould be 1,770, which wants leſs than 1000th part in 2700 of being juſt.

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* By miſtake, the following calculations were made on the ſuppoſition that the loſs was 0,715; the difference being immaterial, the calculations were not repeated.

Again: in the mixture, whoſe ſpecific gravity was 1,719 the ſum of the loſſes was 1779,549, and the weight of the whole 2878,4, the mathematical ſpecific gravity ſhould be $\frac{2778,400}{1779,549} = 1,617$, to which adding 0,100, the ſpecific gravity by obſervation ſhould be 1,717, which is nearly the truth.

By continuing theſe mixtures until the ſpecific gravities by calculation and obſervation nearly coincided, I formed the following table. The extra-tabular proportions are to be ſought in the manner already ſhewn; the two firſt ſeries were formed by analogy.

| Oil and ſpirit of vitriol. | Acid. | Water. | Accrued denſity. | Mathematical ſpecific gravity. | Specific gravity by obſervation | Attract. of the acid to water. | Attract. of water to the acid. |
|---|---|---|---|---|---|---|---|
| Grs. | Grs. | Grs. | | | | | |
| 5,58 | – – | 2,03 | ,000 | 2,032 | 2,032 | ,005 | 0,140 |
| 6,04 | – – | 2,49 | ,005 | 1,884 | 1,889 | ,045 | 0,149 |
| 6,5 | – – | 2,95 | ,045 | 1,774 | 1,819 | ,084 | 0,139 |
| 6,96 | – – | 3,41 | ,084 | 1,687 | 1,771 | 0,100 | 0,137 |
| 7,41 | – – | 3,86 | 0,100 | 1,619 | 1,719 | 0,112 | 0,129 |
| 7,87 | – – | 4,32 | 0,112 | 1,563 | 1,675 | 0,122 | 0,122 |
| 8,33 | – – | 4,78 | 0,122 | 1,515 | 1,637 | 0,129 | 0,112 |
| 8,79 | – – | 5,24 | 0,129 | 1,476 | 1,605 | 0,137 | 0,100 |
| 9,25 | – – | 5,70 | 0,137 | 1,441 | 1,578 | 0,139 | ,084 |
| 9,71 | – – | 6,16 | 0,139 | 1,412 | 1,551 | 0,149 | ,045 |
| 10,17 | – – | 6,67 | 0,140 | 1,385 | 1,525 | ,0140 | ,005 |
| 10,63 | – – | 7,08 | 0,139 | 1,363 | 1,502 | | |
| 11,09 | – – | 7,54 | 0,132 | 1,343 | 1,475 | | |
| 11,55 | – – | 8,00 | 0,127 | 1,325 | 1,452 | | |
| 12,01 | – – | 8,46 | 0,120 | 1,308 | 1,428 | | |
| 12,47 | – – | 8,92 | 0,113 | 1,294 | 1,407 | | |
| 12,93 | – – | 9,38 | 0,106 | 1,280 | 1,386 | | |
| 13,39 | – – | 9,84 | 0,100 | 1,268 | 1,368 | | |
| 13,85 | – – | 10,30 | 0,094 | 1,257 | 1,351 | | |
| 14,31 | – – | 10,76 | 0,088 | 1,247 | 1,335 | | |
| 14,77 | – – | 11,22 | 0,83 | 1,237 | 1,320 | | |
| 15,23 | – – | 11,68 | ,078 | 1,228 | 1,306 | | |
| 15,69 | 3,55 | 12,14 | ,074 | 1,220 | 1,294 | | |
| 16,15 | – – | 12,60 | ,070 | 1,212 | 1,282 | | |
| 16,61 | – – | 13,06 | ,066 | 1,205 | 1,271 | | |
| 17,07 | – – | 13,52 | ,062 | 1,199 | 1,261 | | |
| 17,53 | – – | 13,98 | ,059 | 1,191 | 1,250 | | |
| 17,99 | – – | 14,44 | ,056 | 1,187 | 1,243 | | |
| 18,45 | – – | 14,90 | ,053 | 1,181 | 1,234 | | |
| 18,91 | – – | 15,36 | ,050 | 1,176 | 1,226 | | |
| 19,37 | – – | 15,82 | ,047 | 1,167 | 1,214 | | |
| 19,83 | – – | 16,28 | ,044 | 1,166 | 1,210 | | |
| 20,29 | – – | 16,74 | ,040 | 1,162 | 1,203 | | |
| 20,75 | – – | 17,20 | ,038 | 1,158 | 1,196 | | |
| 21,21 | – – | 17,66 | ,035 | 1,154 | 1,189 | | |
| 21,67 | – – | 18,12 | ,032 | 1,150 | 1,182 | | |
| 22,13 | – – | 18,58 | ,029 | 1,146 | 1,175 | | |
| 22,59 | – – | 19,04 | ,026 | 1,143 | 1,169 | | |
| 23,05 | – – | 19,50 | ,023 | 1,140 | 1,163 | | |
| 23,51 | – – | 19,96 | ,020 | 1,137 | 1,157 | | |
| 23,97 | – – | 20,42 | ,018 | 1,134 | 1,152 | | |
| 24,43 | – – | 20,88 | ,016 | 1,131 | 1,147 | | |
| 24,89 | – – | 21,34 | ,014 | 1,128 | 1,142 | | |
| 25,35 | – – | 21,80 | ,012 | 1,125 | 1,137 | | |
| 25,81 | – – | 22,26 | ,010 | 1,123 | 1,133 | | |
| 26,27 | – – | 22,72 | ,008 | 1,120 | 1,128 | | |
| 26.73 | – – | 23,18 | ,006 | 1,118 | 1,124 | | |

The ſpecific gravity of the moſt concentrated oil of vitriol yet made is, according to Mr. BAUME and BERGMAN, 2,125.

I aſcertained the proportion of acid water and fixed alkali in tartar vitriolate, as before, in nitre and digeſtive ſalt. I found the ſalts, reſulting from the ſaturation of the ſame oil of tartar, with portions of oil of vitriol of different ſpecific gravities, to weigh, at a medium, 12,45 gr. Of this weight only 11,85 gr. were alkali and acid, the remainder therefore was water, *viz.* 0,6 of a grain; conſequently 100 gr. of perfectly dry tartar vitriolate contain 28,51 gr. acid, 4,82 of water, and 66,67 of fixed vegetable alkali. Note, in drying this ſalt I uſed a heat of 240° to expel the adhering acid more thoroughly. I kept it in that heat a quarter of an hour.

According to Mr. HOMBERG, 1 French oz. (or 472,5 gr. Troy) of dry ſalt of tartar required 297,5 gr. Troy of oil of vitriol, whoſe ſpecific gravity was 1,674, to ſaturate it; but, by my calculation, this quantity of fixed alkali would require 325 gr.: a difference which, conſidering our different methods of determining the ſpecific gravity of liquids (his method, *viz.* that by menſuration, giving it always leſs than mine) the different deſiccation of our alkalies, &c. may paſs for inconſiderable.

The reſulting ſalt weighed, according to Mr. HOMBERG, 182 gr. Troy above the original weight of the fixed alkali; but by my experiment it ſhould weigh but 87,7 gr. more; for ∷ 10,5 . 12,45 :: 472,5 . 560,2. It is hard to ſay how Mr. HOMBERG could find this great exceſs of weight both in nitre and tartar vitriolate, unleſs he meant by the *original weight* of the ſalt of tartar the weight of the mere alkaline part, diſtinct from the fixed air it contained: and indeed one would be tempted to think, he did make this diſtinction; for in that caſe the exceſs of weight will be very nearly ſuch as he determined it: for ∴ 10,5 . 8,3 :: 472,5 . 373,3. Now, the whole weight of his nitre was 560,2, as I have above ſhewn: then 560,2 − 373,3 = 116,9, which is only 4 gr. more than he determined it.

Hence he inferred, that 1 oz. (472,5 gr. Troy) of this oil of vitriol contains 291,7 gr. of acid. By my computation it contains but 213,3; but it muſt be conſidered, he made no allowance for the water contained in tartar vitriolate, and imagined the whole of the increaſe of weight proceeded from the acid that is united in it to the fixed alkali. Now the aqueous part in 560 gr. of tartar vitriolate amounts to 37 gr. the remaining difference may be attributed to the different degrees of deſiccation, &c.

## OF THE ACETOUS ACID.

I have made no experiment on this acid; but, by calculating from the experiment of Mr. HOMBERG, I find the ſpecific gravity of the pure acetous acid, free from ſuperfluous water, ſhould be 2,130. It is probable, its affinity to water is not ſtrong enough to cauſe any irregular increaſe in its denſity, at leaſt that can be expreſſed by three decimals; and hence its proportion of acid and water may always be calculated from its ſpecific gravity and abſolute weight.

100 parts of foliated tartar, or (as it ſhould rather be called) acetous tartar, contain well dried 32 of fixed alkali, 19 of acid, and 49 parts of water.

The ſpecific gravity of the ſtrongeſt concentrated vinegar yet made is 1,069.

It is harder to find the point of ſaturation with the vegetable than with the mineral acids; becauſe they contain a mucilage that prevents their immediate union with alkalies, and hence they are commonly uſed in too great quantity. They ſhould be uſed moderately hot, and ſufficient time allowed them to unite.

From theſe experiments it follows:

1ſt. That fixed vegetable alkalies take up an equal quantity of the three mineral acids, and probably of all pure acids; for we have ſeen, that 8,3 grains of pure vegetable alkali (that is, free from fixed air) take up 3,55 gr. of each of theſe acids, and conſequently 100 parts of cauſtic fixed alkali would require 42,4 parts of acid to ſaturate them. Now, Mr. BERGMAN has found, that 100 parts of cauſtic fixed vegetable alkali take up 47 parts of the aerial acid, which, conſidering his alkali might contain ſome water, differs but little from my calculation. It ſhould therefore ſeem, that alkalies have a certain determinate capacity of uniting to acids, that is, to a given weight of acids; and that this capacity is equally ſatiated by that given weight of any pure acid indiſcriminately. This weight is about 2,35 of the weight of the vegetable alkali.

2dly. That the three mineral acids, and probably all pure acids, take up 2,253 times their own weight of pure vegetable alkali, that is, are ſaturated by that quantity.

3dly. That the denſity accruing to compound ſubſtances from the union of their component parts, and exceeding its mathematical ratio, increaſes from a *minimum*, when the quantity of one of them is very ſmall in proportion to that of the other, to a *maximum*, when their quantities differ leſs; but that the attraction, on the contrary, of that part which is in the ſmalleſt quantity to that which is in the greater, is at its *maximum*

*maximum* when the accrued denſity is at its *minimum*, but not reciprocally; and hence the point of ſaturation is probably the *maximum* of denſity and the *minimum* of ſenſible attraction of one of the parts. Hence no decompoſition operated by means of a ſubſtance that has a greater affinity with one part of a compound than with the other, and than theſe parts have to each other, can be complete, unleſs the *minimum* affinity of this third ſubſtance be greater than the *maximum* affinity of the parts already united. Hence few decompoſitions are complete without a double affinity intervenes; and hence the laſt portion of the ſeparated ſubſtance adheres ſo obſtinately to that to which it was firſt united, as all chemiſts have obſerved. Thus, though acids have a greater affinity to phlogiſton than the earths of the different metals have to it, yet they can never totally dephlogiſticate theſe earths but only to a certain degree; ſo though atmoſpheric air, and particularly dephlogiſticated air, attracts phlogiſton more ſtrongly than the nitrous acid does; yet not even dephlogiſticated air can deprive the nitrous acid totally of its phlogiſton, as is evident from the red colour of the nitrous acid when nitrous air and dephlogiſticated air are mixed together. Hence alſo mercury precipitated from its ſolution in any acid, even by fixed alkalies, conſtantly retains a portion of the acid to which it was originally united, as Mr. BAYEN has ſhewn; ſo alſo does the earth of allum, when precipitated in the ſame manner from its ſolution; and thus ſeveral anomalous decompoſitions may be explained. Indeed, I have reaſon to doubt, whether mercury does not attract acids more ſtrongly than alkalies attract them.

4thly. That concentrated acids are, in ſome meaſure, phlogiſticated, and evaporate by union with fixed alkalies.

5thly. That, knowing the quantity of fixed alkali in oil of tartar, we may determine the quantity of real pure acid in any other acid ſubſtance that is difficultly decompoſed, as the ſedatif acid, and thoſe of vegetables and animals; for 10,5 gr. of the mild alkali will always be ſaturated by 3,55 gr. of real acid: and reciprocally, the quantity of acid in any acid liquor being known, the quantity of real alkali in any vegetable alkaline liquor may be found.

## OF THE SPECIFIC GRAVITY OF FIXED AIR IN ITS FIXED STATE.

Being deſirous to know the ſpecific gravity of ſome ſubſtances which are difficultly procured, or at leaſt preſerved for any time, free from fixed air, ſuch as fixed and volatile alkalies, I was induced to ſeek the ſpecific gravity of the former in its fixed ſtate as of an element neceſſary to the calculation of the latter; it being very evident, that its denſity, in its fixed ſtate, muſt be very different from that which it poſſeſſes in its fluid elaſtic ſtate.

I therefore took a piece of white marble, of the pureſt kind, which weighed 440,25 gr. and weighing it in water, found it to loſe 162 gr.; its ſpecific gravity was therefore 2,7175.

Of this marble, reduced to a fine powder, I put 180 gr. into a phial, and expelling the fixed air by the dilute vitriolic acid and heat, I found its quantity amount to 105,28 cubic inches; the thermometer being at 65°, and the barometer between 29 and 30 inches, this bulk of air would, at 55° of FAHRENHEIT, occupy but 102,4 cubic inches; at which temperature, according to the experiment of Mr. FONTANA, a cubic inch of fixed air (the barometer being at 29°½) would weigh 0,57 of a grain; therefore the weight of the whole quantity of fixed air amounted to 58,368 gr. which is nearly one third of the weight of the marble. At this rate, 100 gr of the marble contained 32,42 of fixed air.

To determine the proportion of water and calcareous earth, and alſo the ſpecific gravity of this latter, I put 3009,25 gr. of the ſame marble finely powdered into a crucible, looſely covered; the crucible and its contents, before calcination, weighed 8394 gr. and after remaining fourteen hours in a white heat I found it to weigh 7067,5 gr. The weight of the crucible alone was 5384,75 gr.; therefore the weight of the lime ſingly was 1682,75 gr. The marble then loſt by calcination 1326,5 gr.; 180 gr. of the marble ſhould then loſe 79,343 gr. and 100 gr. ſhould loſe 44,08; but of theſe 44,08, 32,42 were fixed air, as is already ſeen, therefore the remainder, that is, 11,66 gr. were water, and the quantity of pure calcareous earth in 100 gr. of the marble was 55,92 gr.

I next proceeded to diſcover the ſpecific gravity of the lime.

Into a braſs box, which weighed 607,65 gr. and in the bottom of which a ſmall hole was drilled, I ſtuffed as much as poſſible of the finely powdered lime, and then ſcrewed the cover on, and weighed it both in air and water. When immerſed in this latter, a conſiderable quantity of common air was expelled; when this ceaſed, I weighed it. The reſult of this experiment was as follows

| | Gr. |
|---|---|
| Weight of the box in air - | 607,65 |
| Its loſs of weight in water - | 73,75 |
| Weight of the box and lime in air | 1043,5 |
| Weight of the lime ſingly in air - | 435,85 |
| Loſs of weight of the box and lime in water | 256,5 |
| Loſs of weight of the lime ſingly - | 182,3 |

Hence, dividing the abſolute weight of the lime by its loſs in water, its ſpecific gravity was found to be 2,3908.

From theſe *data* I deduced the ſpecific gravity of fixed air in its fixed ſtate; for 100 gr. of marble conſiſt of 55,92 of earth, 32,42 of fixed air, and 11,66 of water; and the ſpecific gravity of the marble is 2,717. Now, the ſpecific gravity of the fixed air, in its fixed ſtate, is as its abſolute weight divided by its loſs of weight in water; and its loſs of weight in water is as the loſs of 100 gr. of marble *minus* the loſſes of the pure calcareous earth and of the water.

$$\begin{array}{lcr} \text{Loſs of 100 gr. of marble} = \frac{100}{2{,}717} & = & 36{,}8 \text{ gr.} \\ \text{Loſs of 55,92 gr. calcareous earth} = \frac{55{,}92}{2{,}390} & = & 23{,}39 \text{ gr.} \\ \text{Loſs of 11,66 gr. water} & = & \underline{11{,}66} \\ & & \underline{35{,}05} \end{array}$$

Then the loſs of the fixed air $36{,}8 - 35{,}05 = 1{,}75$; conſequently, its ſpecific gravity is $\frac{32{,}42}{1{,}75} = 18{,}52$; by which it appears to be the heavieſt of all acids, or even of all bodies yet known, gold and platina excepted.

## OF FIXED VEGETABLE ALKALI.

As the manner of conducting the experiments I made on this ſalt was nearly the ſame as that I uſed in the foregoing (except that to find its ſpecific gravity I weighed it in æther inſtead of water), I ſhall content myſelf, to avoid the repetition of tedious calculation, with relating the reſult of theſe experiments.

1ſt. I found that 100 gr. of this alkali contain about 6,7 gr. of earth, which, according to Mr. BERGMAN, is ſiliceous: this earth paſſes the filter with it when the alkali is not ſaturated with fixed air, ſo that it ſeems to be held in ſolution as in *liquor ſilicum*.

2dly. I found, that the quantity of fixed air in oil of tartar and dry vegetable fixed alkali is various at various times and in various parcels of the ſame ſalt; but that at a medium in the purer alkalies it may be rated at 21 gr. in 100; and hence the quantity of this alkali in any ſolution of it may be very nearly gueſſed at, by adding a known weight of a dilute acid to a given weight of ſuch ſolution, and then weighing it again; for as 21 is to 100, ſo is the weight loſt to the weight of mild alkali in ſuch ſolution.

The ſpecific gravity of mild and perfectly dry four times calcined fixed alkali, free from ſiliceous earth, and containing 21 *per cent.* of fixed air, I found to be 5,0527.

When it contains more fixed air, its ſpecific gravity is probably higher, except it were not perfectly dry: from whence I inferred the ſpecific gravity of this alkali, when cauſtic and free from water, to be 4,234.

From the weight of the aerial acid, in its fixed ſtate, it happens, that fixed alkalies, when united to it, are ſpecifically heavier than when united either to the vitriolic or nitrous acids. Thus Mr. R. WATSON, in the Phil. Tranſ. for the year 1770, p. 337. found the ſpecific gravity of dry ſalt of tartar (including ſiliceous earth) to be 2,761 : whereas the ſpecific gravity of tartar vitriolate was only 2,636, and that of nitre 1,933. The reaſon why nitre is ſo much lighter than tartar vitriolate, is, becauſe it contains much more water, and its union with the alkali is leſs intimate.

Laſtly, I have drawn up a table of the quantity of mild alkali, containing 6,7 *per cent.* of earth (which is its uſual degree of purity) to be found in natural or artificial ſolutions of this alkali, the thermometer at 63°; and though it is not quite accurate, wanting about 1,1 *per cent.* of the truth, yet, I preſume, it may be found uſeful, as this error is eaſily corrected.

Table of the contents of a ſolution of mild vegetable alkali, according to its ſpecific gravity.

| Gr. of the ſolution. | Gr. of alkali. | Gr. of water. | Accrued denſity. | Mathematical ſpecific gravity. | Specific gravity by obſervation |
|---|---|---|---|---|---|
| 64,92 | – – | 38,67 | ,050 | 1,445 | 1,495 |
| 70,60 | – – | 44,35 | ,049 | 1,393 | 1,446 |
| 76,28 | – – | 50,03 | ,048 | 1,356 | 1,404 |
| 81,96 | – – | 55,71 | ,047 | 1,324 | 1,371 |
| 87,64 | – – | 61,39 | ,046 | 1,297 | 1,343 |
| 93,32 | – – | 67,07 | ,045 | 1,274 | 1,319 |
| 99,00 | – – | 72,75 | ,044 | 1,254 | 1,298 |
| 104,68 | – – | 78,43 | ,043 | 1,237 | 1,280 |
| 110,36 | – – | 84,11 | ,042 | 1,223 | 1,265 |
| 115,98 | – – | 89,79 | ,041 | 1,209 | 1,250 |
| 121,66 | – – | 95,4 | ,040 | 1,198 | 1,238 |
| 127,34 | – – | 101,15 | ,039 | 1,187 | 1,226 |
| 133,02 | – – | 106,83 | ,038 | 1,178 | 1,216 |
| 138,7 | – – | 112,51 | ,037 | 1,170 | 1,207 |
| 144,3 | – – | 118,19 | ,036 | 1,162 | 1,198 |
| 149,98 | – – | 123,87 | ,035 | 1,155 | 1,190 |
| 155,66 | – – | 129,55 | ,034 | 1,149 | 1,183 |
| 161,34 | – – | 135,23 | ,033 | 1,143 | 1,176 |
| 167,02 | 26,25 | 140,91 | ,032 | 1,138 | 1,170 |
| 172,70 | – – | 146,59 | ,031 | 1,132 | 1,163 |
| 178,38 | – – | 152,27 | ,030 | 1,128 | 1,158 |
| 184,06 | – – | 157,95 | ,029 | 1,123 | 1,152 |
| 189,74 | – – | 163,63 | ,028 | 1,119 | 1,147 |
| 195,42 | – – | 169,31 | ,027 | 1,115 | 1,142 |
| 201,10 | – – | 174,99 | ,026 | 1,112 | 1,138 |
| 206,78 | – – | 180,67 | ,025 | 1,108 | 1,133 |
| 212,46 | – – | 186,35 | ,024 | 1,105 | 1,129 |
| 218,14 | – – | 192,03 | ,023 | 1,100 | 1,123 |
| 223,82 | – – | 197,71 | ,022 | 1,099 | 1,121 |
| 229,50 | – – | 203,39 | 0,21 | 1,097 | 1,118 |
| 235,18 | – – | 209,07 | ,020 | 1,094 | 1,114 |
| 240,86 | – – | 214,75 | 0,19 | 1,092 | 1,111 |
| 246,54 | – – | 220,43 | ,018 | 1,089 | 1,107 |
| 252,12 | – – | 226,11 | 0,17 | 1,087 | 1,104 |
| 257,80 | – – | 231,79 | ,016 | 1,085 | 1,101 |
| 263,48 | – – | 237,47 | ,015 | 1,083 | 1,098 |
| 269,16 | – – | 243,15 | ,014 | 1,081 | 1,095 |

| Gr. of the ſolution. | Gr. of alkali. | Gr. of water. | Accrued denſity. | Mathematical ſpecific gravity. | Specific gravity by obſervation |
|---|---|---|---|---|---|
| 274,78 | – – | 248,83 | ,013 | 1,079 | 1,092 |
| 280,46 | – – | 254,51 | ,012 | 1,077 | 1,089 |
| 286,14 | – – | 260,19 | ,011 | 1,076 | 1,087 |
| 291,82 | – – | 265,87 | ,010 | 1,074 | 1,084 |
| 297,50 | – – | 271,55 | ,009 | 1,070 | 1,079 |
| 303,18 | – – | 277,23 | ,008 | 1,069 | 1,077 |
| 308,86 | 26,25 | 282,91 | ,007 | 1,068 | 1,075 |
| 314,54 | – – | 288,59 | ,006 | 1,066 | 1,072 |
| 319,22 | – – | 294,27 | ,005 | 1,065 | 1,070 |
| 324,90 | – – | 300,45 | ,004 | 1,064 | 1,068 |
| 330,58 | – – | 306,13 | ,003 | 1,063 | 1,066 |
| 336,26 | – – | 311,81 | ,002 | 1,062 | 1,064 |
| 341,94 | – – | 317,49 | ,001 | 1,061 | 1,062 |

Impure vegetable fixed alkalies ſuch as pearl aſh, pot aſhes, &c. contain more fixed air, as appears by the experiments of Dr. LEWIS. Pearl aſh, according to Mr. CAVENDISH, contains 28,4 or 28,7 *per cent.* of fixed air. Hence in lyes of equal ſpecific gravity with thoſe of a purer alkali, the quantity of ſaline matter will be more probably in the ratio of 28,4 or 28,7 to 21; but this ſurplus weight is only fixed air; and hence even in theſe lyes the quantity of depurated ſalt they will afford will be found by the above table. Much alſo depends on their age, the oldeſt containing moſt fixed air.